AD 691794

CODE IDENT. NO. 77272

NUMBER D8-1038

TITLE Fatique Properties of 17-4 PH and 15-5 PH Steel in the H-900 and H-1050 Condition

BOEING

VERTOL DIVISION

REV LTR

THE BOEING COMPANY

VERTOL DIVISION · MORTON, PENNSYLVANIA

CODE IDENT. NO. 77272

NUMBER D8-1038

TITLE Fatigue Properties of 17-4 PH and 15-5 PH Steel in the H-900 and H-1050 Condition

FOR LIMITATIONS IMPOSED ON THE USE OF THE INFORMATION CONTAINED IN THIS DOCUMENT AND ON THE DISTRIBUTION OF THIS DOCUMENT, SEE LIMITATIONS SHEET.

MODEL ______ CONTRACT ______

ISSUE NO. ______ ISSUED TO: ______

PREPARED BY M. [illegible] DATE 6/24/68

APPROVED BY [illegible] DATE 6/26/68

APPROVED BY [illegible] DATE 6/28/68

APPROVED BY [illegible] DATE 7/1/68

FORM 46280 (3/67)

LIMITATIONS

DDC AVAILABILITY NOTICE:

Distribution of this document is unlimited. It may be released to the Clearinghouse, Department of Commerce, for sale to the general public.

This document is controlled by Materials Engineering 8-7525

- All revisions to this document shall be approved by the above noted organization to release.

ACTIVE SHEET RECORD

SHEET NUMBER	REV LTR	ADDED SHEETS				SHEET NUMBER	REV LTR	ADDED SHEETS			
		SHEET NUMBER	REV LTR	SHEET NUMBER	REV LTR			SHEET NUMBER	REV LTR	SHEET NUMBER	REV LTR
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											

FORM 46283 (12/65)

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL

ABSTRACT

The rotating beam fatigue properties of 17-4 PH and 15-5 PH steels were evaluated for the H-900 and H-1050 conditions. In addition, the effect of shot peening on 15-5 PH was investigated. The results indicate that the two alloys behave similarly. Over aging to the H-1050 results in a 5% decrease in the endurance limit when compared to the H-900 condition. Shot peening improves the finite fatigue life by an order of magnitude.

TABLE OF CONTENTS

I. INTRODUCTION

The primary purpose of this program is the comparison of the fatigue properties of 17-4 PH steel and 15-5 PH steel in the H-900 condition with the slightly overaged H-1050 condition. In addition, the effects of shot peening on the fatigue properties of 15-5 PH was also studied. The H-1050 condition while decreasing the ultimate tensile and yield strengths, results in improved transverse ductility and toughness (See Tables I and II). The overaged condition also exhibits a greater stress corrosion resistance than does the H-900 condition. (1,2)

Recognizing that the transverse properties of 17-4 PH are governed to a large extent by the delta ferrite present in the microstructure, 15-5 PH, which essentially is ferrite free, was developed by the Armco Steel Corporation. In addition to higher transverse ductility, 15-5 PH steel also has the advantage over 17-4 PH of being able to be reliably inspected by magnetic particle methods rather than by penetrant techniques. Because delta ferrite has magnetic properties different from those of martensite, the delta ferrite in 17-4 PH can sometimes give false magnetic particle inspection indications. Because of the inspection advantages of 15-5 PH over 17-4 PH and the improved transverse ductility, this program was undertaken to compare the fatigue properties of 15-5 PH steel with the better known 17-4 PH steel alloy.

II. MATERIAL AND TEST PROCEDURES

A. Material

The 15-5 PH steel used in this investigation was 0.50 inch round bar stock from Armco Steel Corporation heat #62426, supplied by the P. Frasse Co.. The 17-4 PH steel, was 0.50 inch round bar stock taken from production stores. No mill heat records were available.

II. (Continued)

B. Chemical Analysis

The chemistry of the material met the requirements of the applicable specifications, as shown in Table 3.

C. Heat Treatment

The bar stock of both alloys was received in the solution annealed condition (Condition A). Standard R.R. Moore rotating beam fatigue specimens were rough machined 0.020" oversized, and were precipitation hardened per the following schedule:

CONDITION REQUIRED	TEMPERATURE	TIME
H-900	900°F	1 Hr.
H-1050	1050°F	4 Hrs.

The hardnesses resulting from the above precipitation hardening treatments were as follows:

	HARDNESS, R/C	
ALLOY	H-900	H-1050
17-4 PH	45	36
15-5 PH	46	37

D. Fatigue Test Specimens

The fatigue test specimens were finished machined after precipitation hardening to the configuration and dimensions shown in Figure 1.

E. Shot Peening

The shot peening of the 15-5 PH specimens was performed by the Metal Improvement Co., Hackensack, N. J. per MS 21.01. The specimens were in the aged and final machined configuration at the time of shot peening. Only the test section of the specimen was shot peened; the grips were protected by masking.

II. E. (Continued)

Shot peening was accomplished by the use of two nozzles positioned straddling the longitudinal axis of the specimen, and 60° to the horizontal specimen plane. The nozzles were automatically oscillated parallel to the specimen and the specimen rotated at 20 RPM. The shot size was S170, and the recorded arc height was .010A2.

III. TEST RESULTS

A. Fatigue Tests

1. Effect of Precipitation Heat Treatment

The results of the rotating beam fatigue tests are tabulated in Tables 4, 5, 6, 7, 8, and 9 and graphically displayed in Figures 2, 3, 4, and 5. As can be seen, a reduction of less than 5% in endurance limit occurs when the precipitation hardening temperature is increased from 900°F to 1050°F. Similarly, a small decrease in life occurs in the finite region of the S/N curve. This is more noticeable in the 15-5 PH alloy than in the 17-4 PH alloy.

2. Effect of Shot Peening

The effect of shot peening on 15-5 PH in the H-900 and H-1050 conditions, is shown in Figures 5 and 6. As can be seen, no definite knee in the S/ N curve was found for the shot peened samples at 10^7 cycles, and,as a result, no definite statements can be made concerning endurance limits. However, in the finite life range (less than 10^7 cycles), improvements of at least an order of magnitude are noted. Of interest is the observation that shot peening seemed to be more beneficial to material in the H-900 condition then in the H-1050 condition.

III. (Continued)

B. Metallographic Examination

Typical longitudinal micro-structures are shown in Figure 6. In their gross features, both alloys are identical when subjected to the same precipitation treatments. The most noticeable difference is the absence of ferrite stringers in the 15-5 PH. However, ferrite was present in the form of spheroids, the largest of which was 0.00006 inches in diameter.

The effect of overaging on the microstructure of 15-5 PH is shown in Figure 7, and is typical of both alloys. Coalescence and growth of the copper rich hardening phase is evident in the specimen aged at 1050°F.

C Fractographic Examination

Typical fracture faces of failed specimens are shown in Figure 8. Macroscopic examination revealed that all origins were at the surface and, in general, the macroscopic fatigue characteristics of both alloys was identical. Examination of the shot peened 15-5 PH specimen revealed that the primary fatigue origins were located .002" to .006" below the surface. Most specimens also contained one or more secondary origins. Typical examples are shown in Figure 9.

D. Electron Fractography

Electron fractographic evaluation of selected samples did not reveal any differences in the two alloys. However, in the H-1050 condition, clusters of the copper rich precipitate were observed on the fracture face. This is shown in Figure 10.

IV. DISCUSSION

The results of the tests and literature survey indicates a similarity in the mechanical and endurance properties of the two alloys investigated. The major difference lies in the superior transverse ductility of 15-5 PH with respect to 17-4 PH.

Both alloys reportedly exhibit the same resistance to stress corrosion cracking, with the H-1050 condition being preferred to the H-900 condition. Thus, the 5% decrease in the endurance limit of H-1050 material would be off-set by significantly increased stress corrosion resistance.

Since 15-5 PH contains virtually no delta ferrite, it lends itself to magnetic particle inspection more readily than does 17-4 PH.

V. CONCLUSIONS

A. The fatigue properties of 17-4 PH and 15-5 PH steels are similar.

B. Increasing the aging temperature of 17-4 PH and 15-5 PH from 900°F to 1050°F results in a decrease in endurance limit of 5%.

C. These alloys exhibit improved resistance to stress corrosion when in the overaged condition.

D. 15-5 PH offers inspection advantages over 17-4 PH in that it is not subject to irrelevant magnetic particle indications due to free delta ferrite.

E. Shot peening improves the finite life of 15-5 PH by an order of magnitude.

REFERENCES

1. Armco Product Data Bulletin S-6

2. Armco Product Data Bulletin S-21

TABLE I

COMPARISON OF TENSILE PROPERTIES AND TEST DIRECTION OF 17-4 IN THE H-925 and H-1025 CONDITION*

Test Direction	Heat Treat Condition	UTS Psi	2% Yield Psi	Elong. in 2"%	Red in Area %
Longitudinal	H-925	194,800		17	53.5
	H-1025	163,000	160,000	17	58.0
Transverse	H-925	195,000		4.5	5.0
	H-1025	162,000	159,000	13.0	32.0

*Armco Product Data Bulletin S-6

TABLE 2

COMPARISON OF TENSILE PROPERTIES AND TEST DIRECTION
OF 15-5 PH IN THE H-925 and H-1025 CONDITION*

Test Direction	Heat Treat Condition	UTS Psi	2% Yield Psi	Elong. in 2"%	Red in Area %
Longitudinal	H-925	190,000	175,000	14	54
	H-1025	170,000	165,000	15	56
Transverse	H-925	190,000	175,000	11	35
	H-1025	170,000	165,000	12	42

* Armco Product Data Bulletin S-21

TABLE 3

CHEMICAL ANALYSIS OF 15-5 PH & 17-4 PH

Element	15-5 PH Actual (%)	15-5 PH Req'd (AMS 5659)	17-4 PH Actual (%)	17-4 PH Req'd(AMS 5643)
Cr	15.54	14.0 - 15.5	16.50	15.5 - 17.5
Ni	4.57	3.5 - 5.5	4.20	3.0 - 5.0
Cu	3.50	2.5 - 4.5	4.20	3.0 - 5.0
C	0.039	.07 Max.	0.045	.07 Max.
Mn	0.22	1.0 Max.	0.33	1.0 Max.
P	0.020	.040 Max.	0.18	.040 Max.
S	0.008	.030 Max.	0.010	.030 Max.
Cb	0.33	5 x C - 0.45	0.20	5 x C - 0.45
Ta	0.02		0.02	
Si		1.0 Max.	0.59	1.0 Max.
Co			0.27	0.15 - 0.45

TABLE 4

FATIGUE RESULTS 17-4 PH, H-1050 CONDITION

Stress Ksi	Cycles to Failure	Specimen No.
130	80,000	18
120	261,000	15
110	663,000	16
105	2,053,000	17
105	2,431,000	22
103	531,000	19
103	822,000	20
100	550,000	23
98.5	1,317,000	28
97.5	13,866,000 Runout	27
95	1,713,000	24
95	11,643,000 Runout	21
94	7,800,000	30
93	12,801,000 Failure	26
91	13,267,000 Failure	29
90	16,504,000 Runout	25

TABLE 5

FATIGUE RESULTS, 17-4 PH, H-900 CONDITION

Stress Ksi	Cycles to Failure		Specimen No.
130	$.082 \times 10^6$		1
120	$.184 \times 10^6$		2
110	$.264 \times 10^6$		3
105	$.795 \times 10^6$		14
105	1.622×10^6		13
100	1.952×10^6		4
98	3.964×10^6		12
97.5	3.063×10^6		6
97	1.252×10^6		8
97	3.098×10^6		9
96	1.980×10^6		10
96	38.000×10^6	Runout	7
95	11.667×10^6	Runout	11
95	12.052×10^6	Runout	5

TABLE 6

FATIGUE RESULTS, 15-5 PH, H-1050 CONDITION

Stress Ksi	Cycles to Failure	Specimen No.
130	.052 x 10^6	46
120	.074 x 10^6	37
110	.161 x 10^6	48
100	1.506 x 10^6	39
98	.711 x 10^6	45
98	.967 x 10^6	40
95	.846 x 10^6	38
94	.964 x 10^6	42
94	16.339 x 10^6 Runout	43
92.5	.667 x 10^6	47
92.5	39.000 x 10^6 Runout	41
90	10.916 x 10^6 Runout	44

TABLE 7

FATIGUE RESULTS, 15-5 PH, H-900 CONDITION

Stress Ksi	Cycles to Failure	Specimen No.
130	$.089 \times 10^6$	23
120	$.098 \times 10^6$	16
115	$.236 \times 10^6$	14
110	$.419 \times 10^6$	24
105	$.357 \times 10^6$	13
102	$.318 \times 10^6$	20
100	1.246×10^6	18
100	11.500×10^6 Runout	23
99	$.241 \times 10^6$	22
97	11.037×10^6 Runout	19

TABLE 8

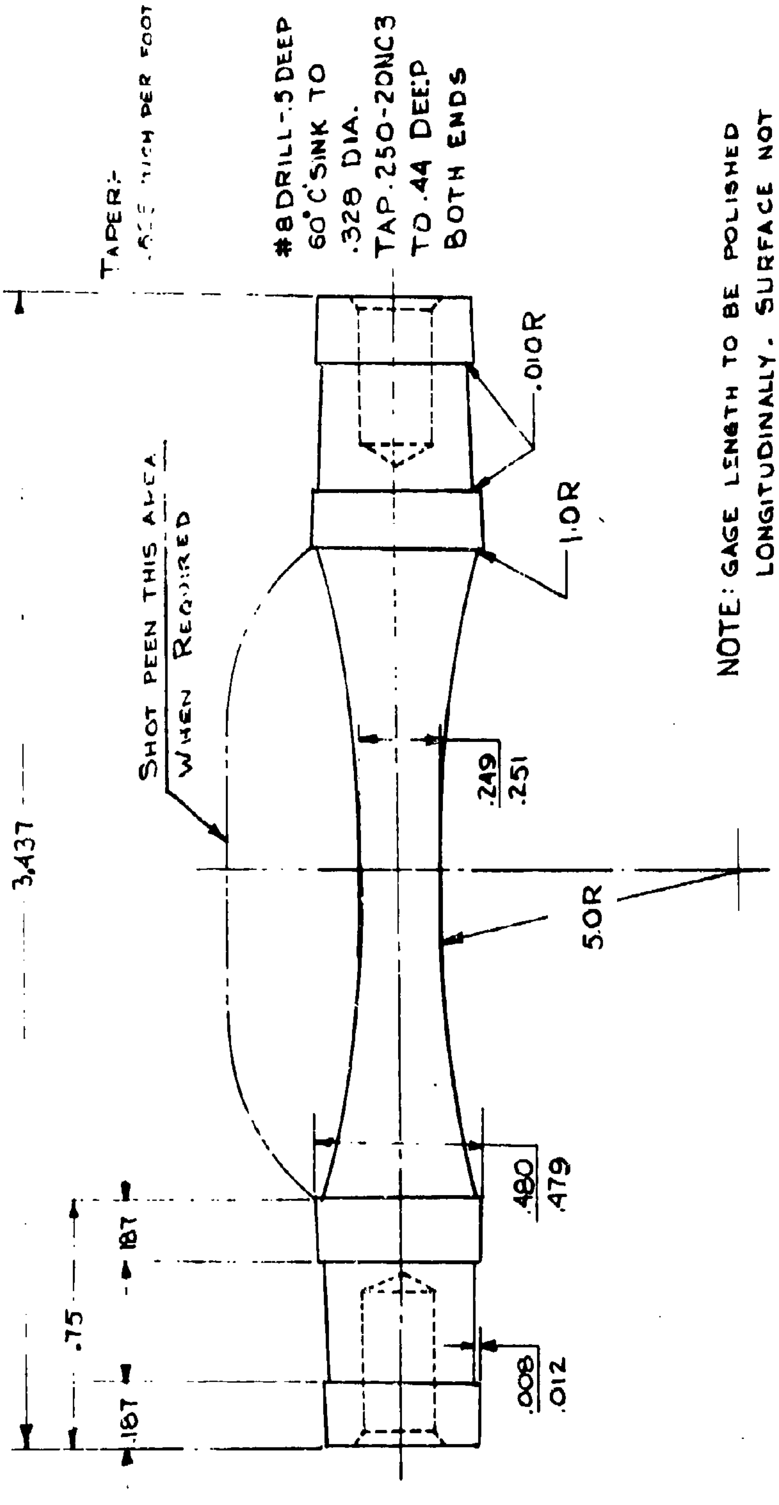
FATIGUE RESULTS, 15-5 PH, H-1050 CONDITION
SHOT PEENED WITH S-170 SHOT

Stress Ksi	Cycles to Failure	Specimen No.
140	38,000	7
135	122,000	1
130	147,000	9
130	168,000	2
123	599,000	11
120	544,000	3
110	6,881,000	4
110	8,972,000	10
110	9,356,000	8
105	7,641,000	6
100	10,046,000 Runout	5

TABLE 9

FATIGUE RESULTS, 15-5 PH, H-900 CONDITION
SHOT PEENED WITH S-170 SHOT

Stress Ksi	Cycles to Failure	Specimen No.
150	182,000	31
145	321,000	32
140	519,000	25
140	645,000	34
140	912,000	30
135	2,542,000	33
130	3,791,000	26
125	3,596,000	35
125	3,602,000	36
125	4,375,000	29
120	5,182,000	27
115	7,168,000	28



NOTE: GAGE LENGTH TO BE POLISHED LONGITUDINALLY. SURFACE NOT TO EXCEED 6 RMS

FIGURE 1 R.R. MOORE FATIGUE BAR

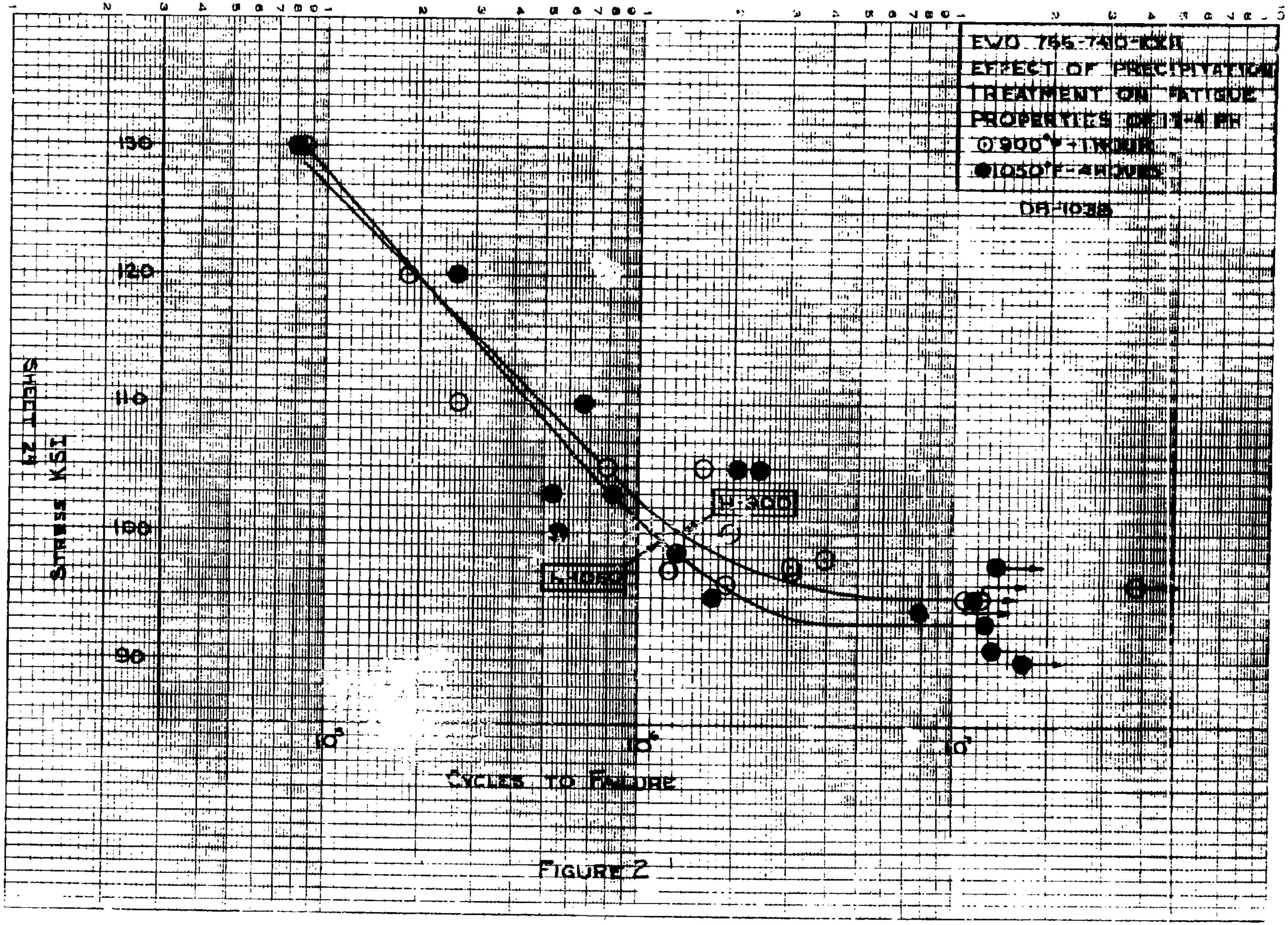


FIGURE 2

SHEET 24

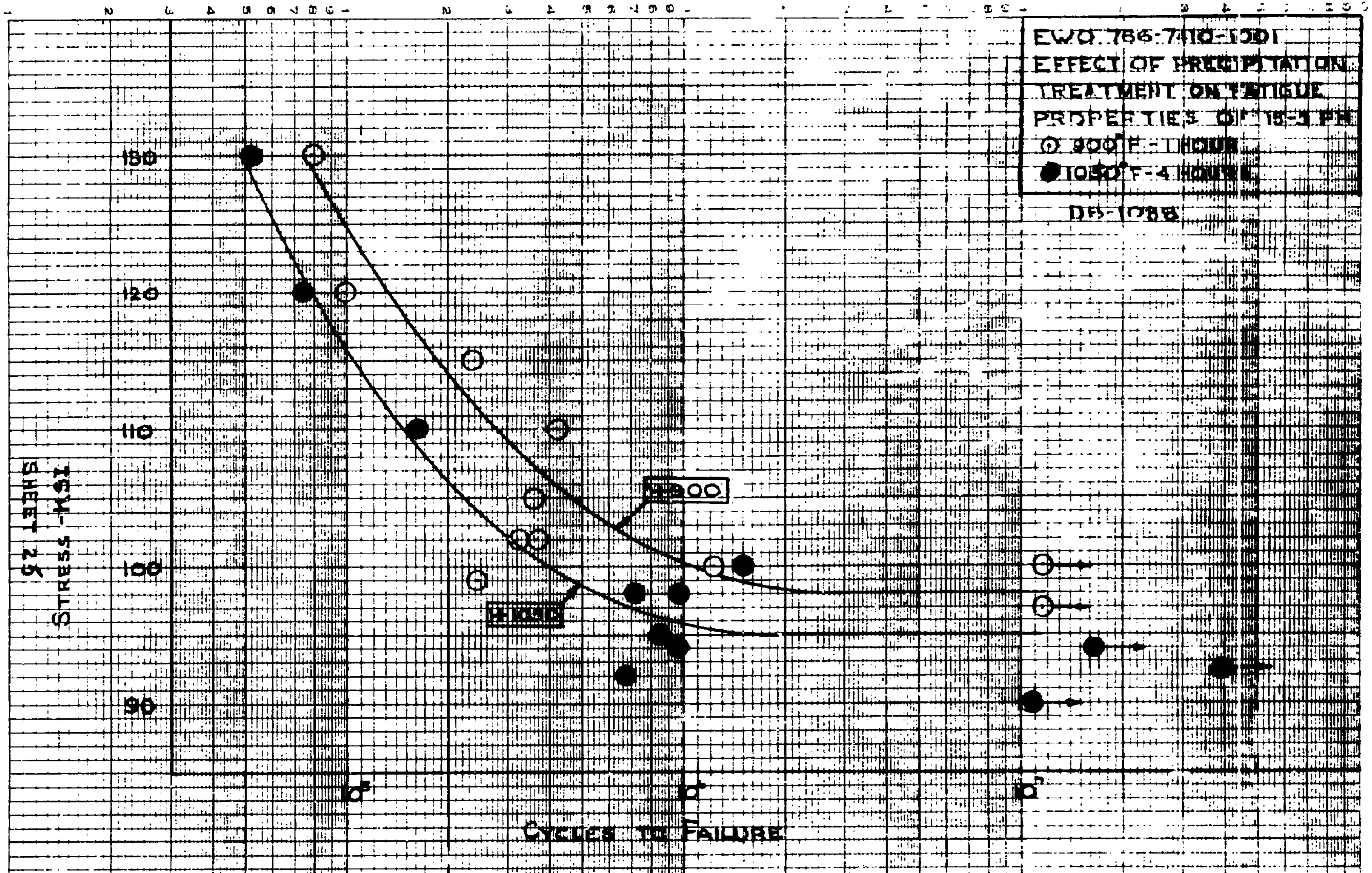


FIGURE 3

SHEET 25

1. 340R-L410 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
4 CYCLES X 10 DIVISIONS PER INCH

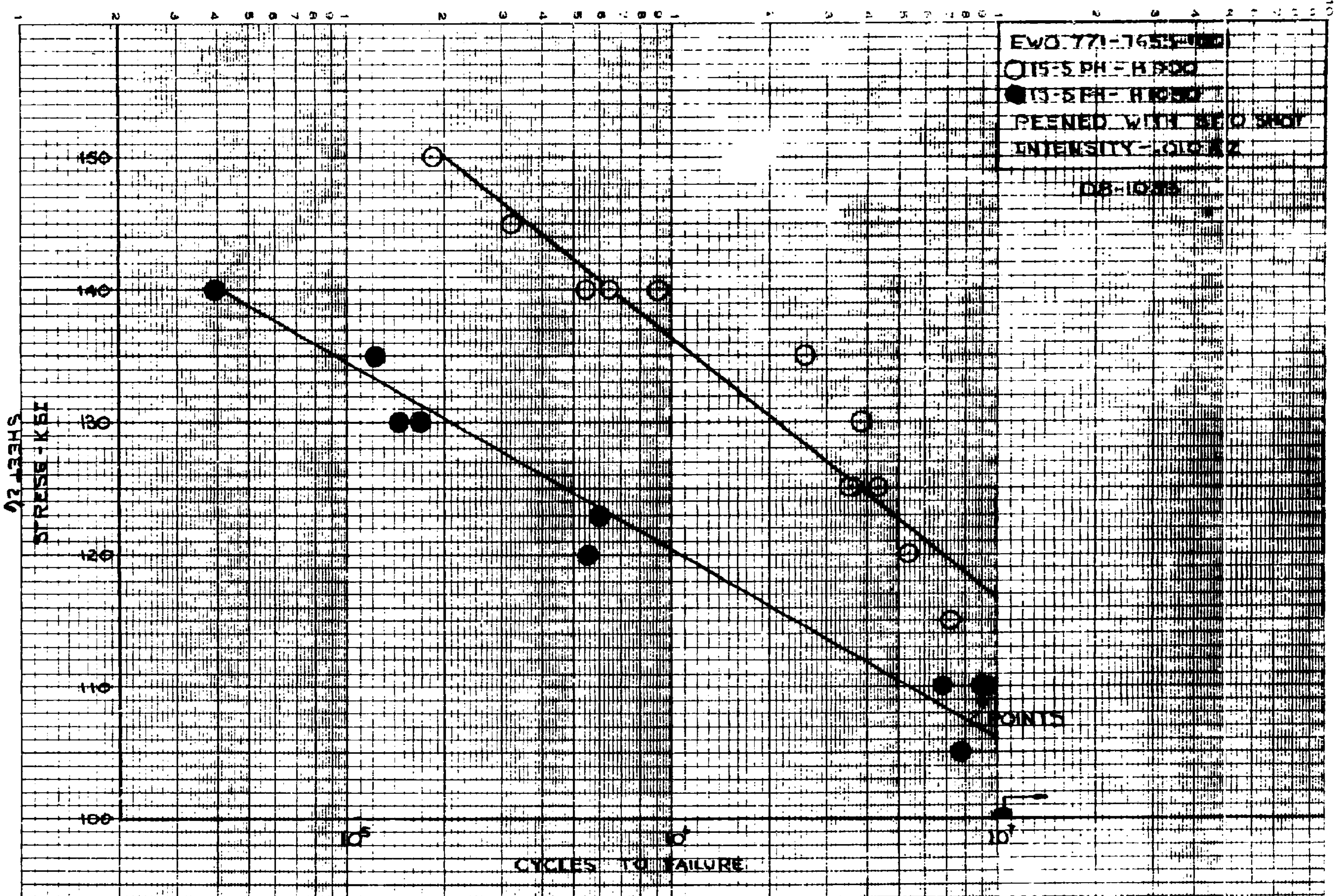


FIGURE 4

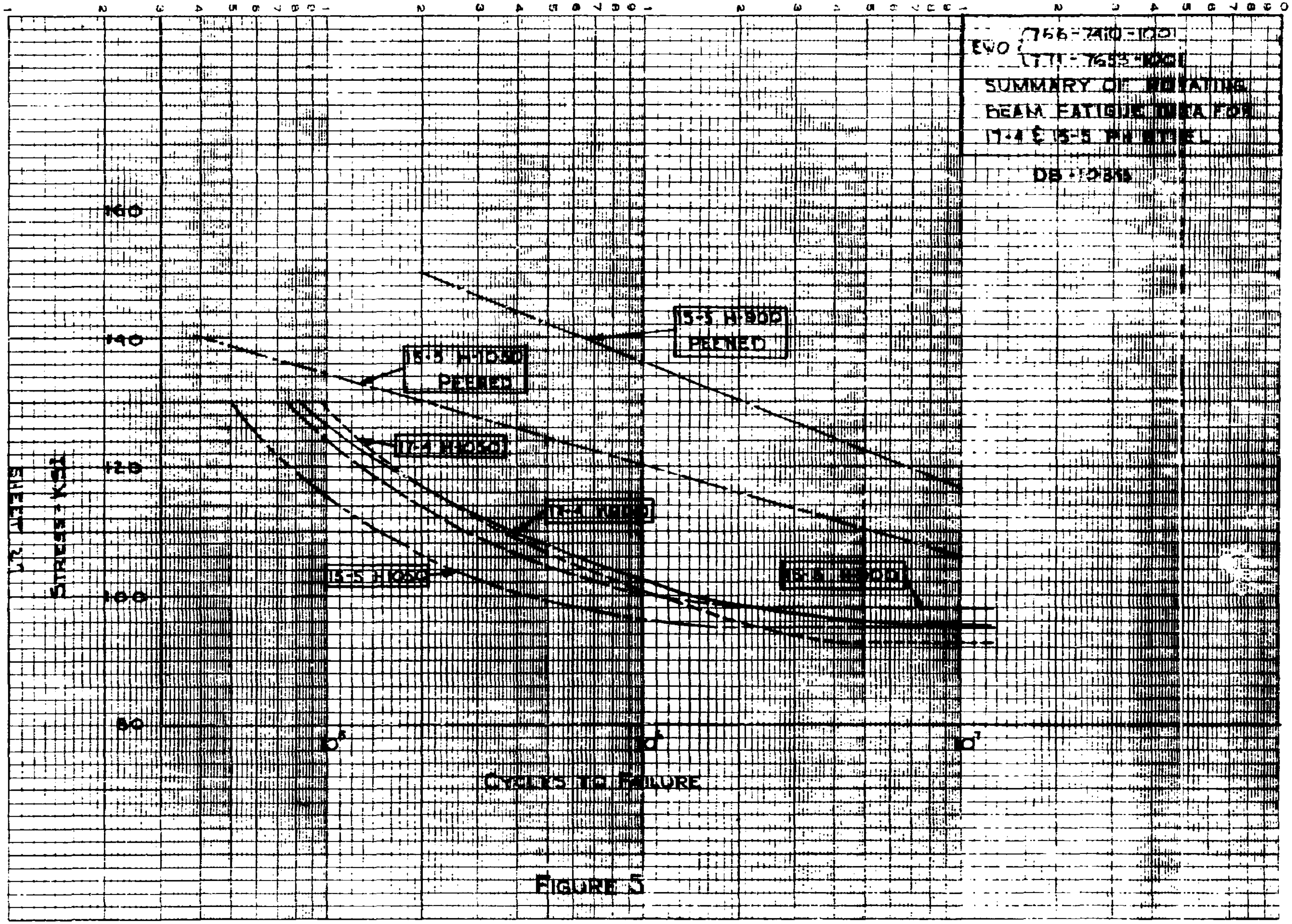
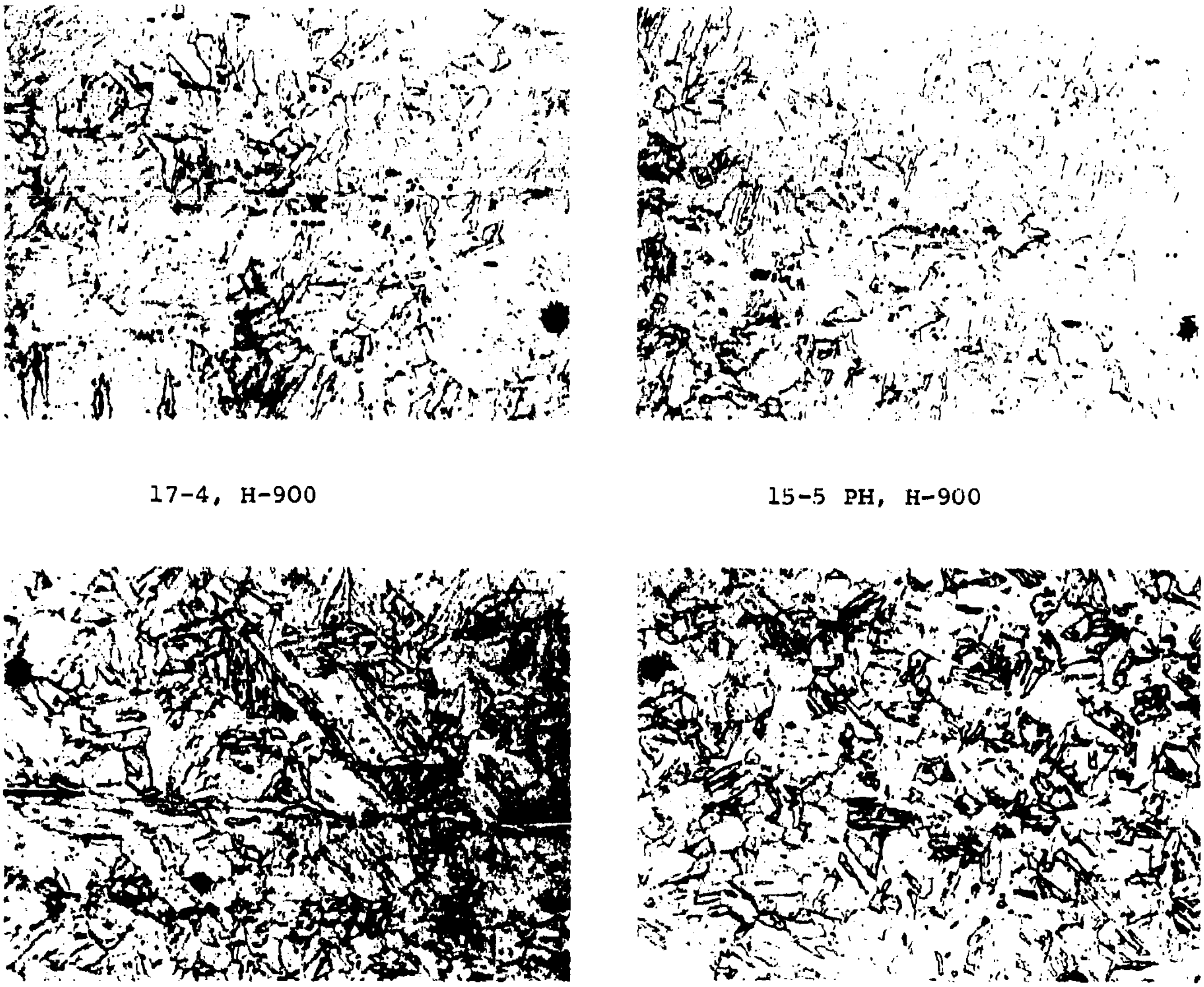


FIGURE 5

SHEET 27

500X

HCl & Picric Acid Etch



17-4, H-900

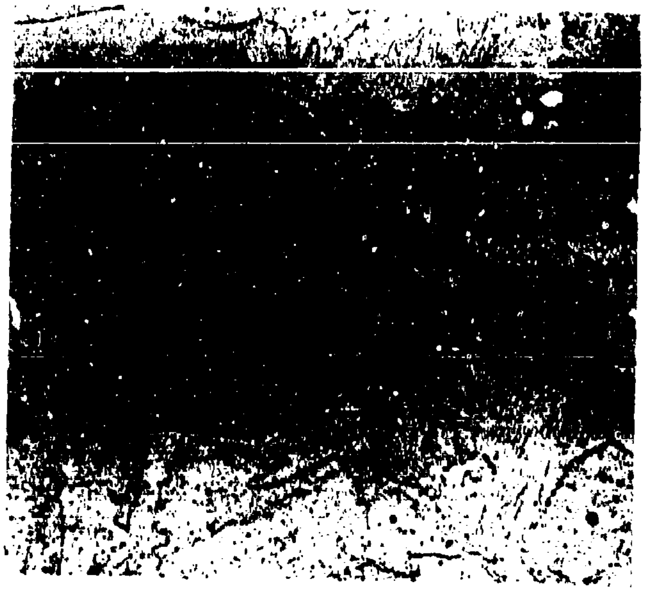
15-5 PH, H-900

17-4, H-1050

15-5 PH, H-1050

NOTE DELTA FERRITE STRINGER
INDICATED BY ARROWS
TYPICAL MICROSTRUCTURES OF 17-4 PH and 15-5 PH STEELS IN THE
H-900 and H-1050 CONDITIONS.

FIGURE 6



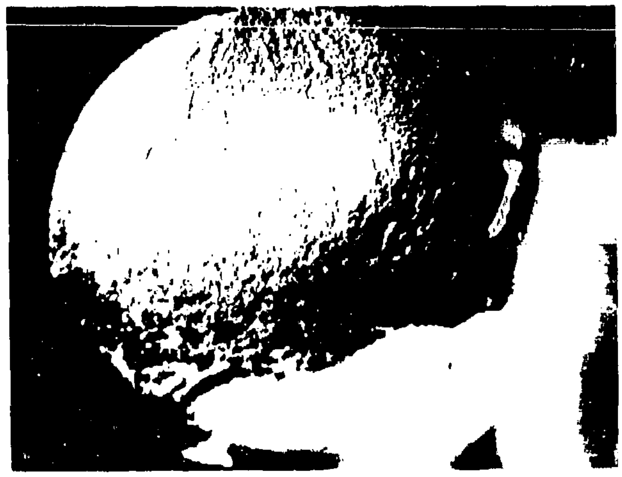
H-900 CONDITION

H-1050 CONDITION, NOTE DEGREE OF PRECIPITATION

ELECTRON PHOTOMICROGRAPHS OF TYPICAL 15-5 PH MICROSTRUCTURES 3000X, HCl & Picric Acid Etch

FIGURE 7

17-4 PH, H-900 CONDITION



17-4 PH, H-1050 CONDITION

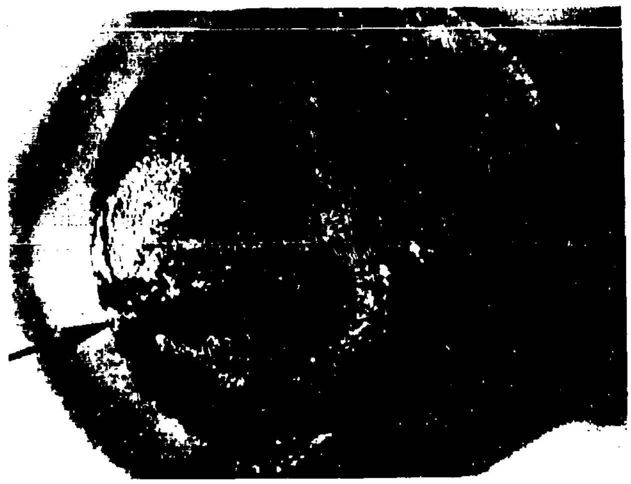
15-5 PH, H-900 CONDITION

15-5 PH, H-1050 CONDITION

FIGURE 13X, TYPICAL FRACTURE FACES OF 17-4 PH and 15-5 PH.

ARROWS INDICATE ORIGINS.

FIGURE 8

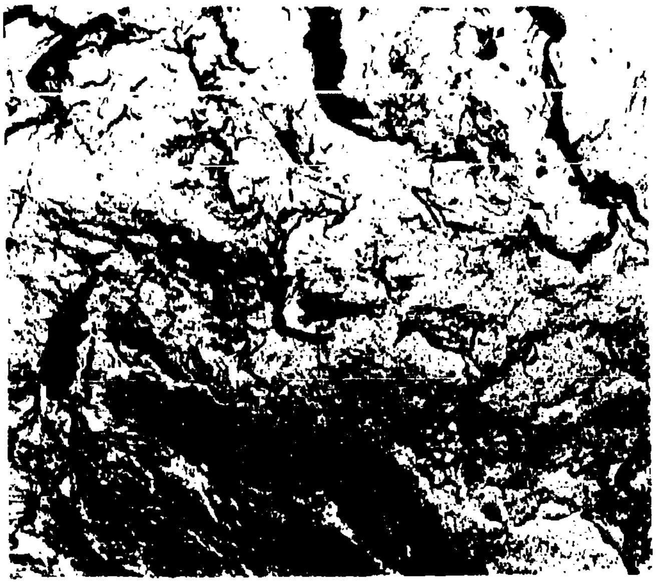


15-5 PH, H-900 CONDITION

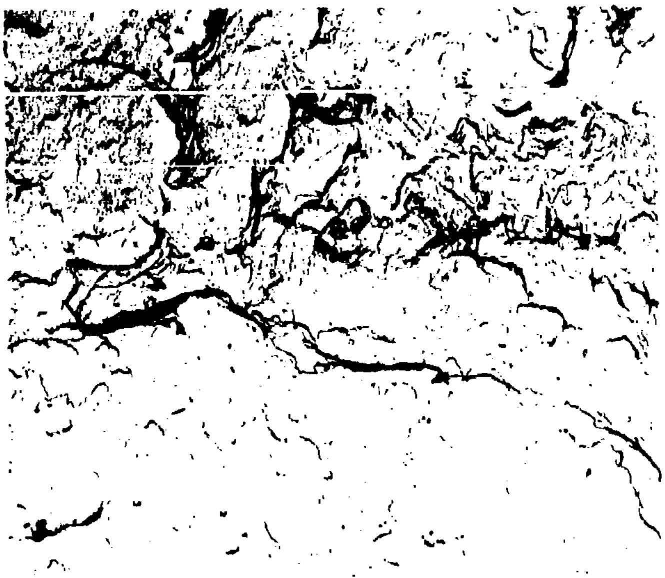
15-5 PH, H-1050 CONDITION

TYPICAL FRACTURE FACES OF SHOT PEENED 15-5 PH STEEL.
ARROWS INDICATE PRIMARY ORIGINS - NOTE SECONDARY ORIGINS.

FIGURE 9



17-4 PH, H-900 CONDITION



15-5 PH, H-900 CONDITION

17-4 PH, H-1050 CONDITION

15-5 PH, H-1050 CONDITION

ELECTRON FRACTOGRAPHS OF TYPICAL FRACTURE FACES. ARROWS INDICATE COPPER RICH PRECIPITATE INDICATIVE OF THE H-1050 CONDITION.

FIGURE 10